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ABSTRACT

This study attempted to gather empirical evidence to guide educators in their teaching of linear measurement to primary school children. It attempted to answer the question "What modes of instruction are most effective for teaching linear measurement concepts to conservers and nonconservers of length?" (as defined by Jean Piaget), using a nine-item test designed by the investigators, and various modes of instruction (as defined by Jerome Bruner). The authors report that: (1) primary pupils can learn to measure with non-standard and standard units of length; (2) iterative measurement is a difficult concept for them; (3) the manipulative mode is more effective than the graphic and symbolic modes; and (4) conservation measures and I.Q. measures seem to overlap in their effect on learning. (Author/SA)

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Validation of Three Instructional Modes With
Conservers and Nonconservers of Length
Using Linear Metric Measurement¹

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Rationale

This study is based upon two basic theories: Piaget's length conservation and Bruner's modes of instruction. Briefly, length conservation is the recognition that an object's length remains the same regardless of perceptual transformations which are performed. For example, pieces of yarn are first judged by a child to be equal in length. Then one piece is bent. A nonconservor (NC) will now declare the pieces to be of unequal length. A conservor (C) will maintain they are still of equal length and will give one of the following logical reasons for his/her statement: (1) identity/invariant quantity--nothing has been added or taken away, (2) compensation--one dimension makes up for another, and (3) reversibility--can return to its original position.

Piaget, Inhelder, and Szeminska (1960) have implied in their writings that conservation of length must be attained before a child can understand length measurement, particularly iterative measurement which requires movement of a small unit along a longer object.

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At least two teacher preparation textbooks in mathematics education (Copeland, 1970; Heimer & Trueblood, 1977) present the same recommendation: If a child does not conserve length, postpone instruction in length measurement until he/she does.

A second theory underlying this study involves the following modes of instruction as defined by Bruner (1966): (1) symbolic (S)--an abstract way of presenting information using verbal, written, or mathematical materials, (2) iconic (I)--a graphic way of presenting information using perceptual, two dimensional materials such as pictures, and (3) enactive (E)--a manipulative way of presenting information using three dimensional materials and demonstrations.

Szabo, Trueblood, Gouty, and Milhoan (1977) used these modes to develop the matrix shown in Figure 1. This matrix provides us with a practical tool for examining the activities which occur in classrooms by pinpointing the modes of teacher input and student output.

Further work was done by Szabo and Trueblood (1977) to tie together Piaget's and Bruner's theories. They developed a matrix (Figure 2) to illustrate a hypothesis about which modes of instruction ought to be used to teach children at given Piagetian cognitive levels. It can be seen that the EE (manipulative input and output) instructional mode is considered the easiest and should be used with children at the lowest cognitive level. As the mode used becomes less concrete and increasingly abstract, it is hypothesized that the cognitive level of the child must be more advanced.

Hypotheses

The study being discussed here attempted to relate modes of instruction and length conservation by testing the following hypotheses:

1. Students taught under the EE mode will score higher than those taught under the IE and SE modes.
2. Length conservers (C) will score higher than nonconservers (NC) under all treatments.
3. Conservers will score higher on iterative measurement items than will nonconservers.

Method

Subjects

One hundred forty-five kindergarten through second grade children in a central Pennsylvania school district were tested for conservation. Sixty-six were selected for the study and were randomly assigned to three treatment groups: eleven C and eleven NC in each. Transitional students were not used in the study.

Design

The design which used a stratified random assignment, three treatment groups and posttest only is presented in Figure 3.

In the first week of the study, T1 was the only group to receive any instruction; it was abstract. During the second week, groups T1 and T2 received graphic instruction. During the third week, all three groups received manipulative instruction.

Treatment

The test for length conservation consisted of four tasks which were adapted from the studies by Inhelder, et al., (1974) and Gelman (1969).

1. Continuous/Unequal--used two pieces of yarn of unequal length (15 and 10 cm)
 - a. Align ends, both pieces straight
 - b. Bend longer piece so as to align both ends

2. Discontinuous/Equal--used ten purple Cuisenaire rods (4 cm)

- a. Arrange into two equal "roads" of five each--ends aligned
- b. Rearrange one "road" to make it look shorter than the other

||

3. Discontinuous/Unequal--used ten purple Cuisenaire rods (4 cm)

- a. Arrange two unequal "roads" with left end aligned--six and four rods
- b. Rearrange shorter road to present a slight optical illusion of being equal in length

4. Continuous/Equal--used two pieces of yarn of equal length (10 cm)

- == a. Align both ends of yarn so that equal length is seen
- == b. Rearrange one piece to present a slight optical illusion of different length.

The procedure followed in all the above tasks was (1) ask S to judge the length of the two "roads" when placed side-by-side, one edge aligned; (2) change perceptual position of one "road;" (3) ask S to judge length of the "roads" again; and (4) ask S for reasons behind his/her answer in number three above.

Two points were awarded for each task--one for the correct length judgment and one for the correct (logical) reason for the answer.

For the purposes of this study, S with a score of 7-8 points was considered to be a conserver (C) and S with a score of 0-2 points was a nonconserver (NC).

The thirty-three C and thirty-three NC were randomly assigned to three T groups, which were given instruction in linear measurement for thirty minutes per day for four days each week. The fifth day in each week was devoted to testing.

Each week the mode of instruction used was varied. That is, during the first week abstract (verbal) instruction was used. During the second week only

graphic (pictures and posters) instruction was used. During the third week, manipulative instruction was used. In all cases, student output was in the enactive mode. Thus, this study examined variations in teacher input (Column 1 in Figure 1).

The content of instruction remained the same each week and included: (1) relational terms (longer, shorter, same length as), (2) use of nonstandard units to compare length of objects shorter than the units, (3) use of small nonstandard units to iteratively measure longer objects, and (4) use of cm rulers to measure shorter objects or pictures.

Test tasks were kept congruent with the instructional content listed above. Each test consisted of nine points: (1) identify shortest, (2) identify longest, (3) identify same length as, (4) align ends of nonstandard unit to illustrate same length as, (5) build tower to same length as unit in number four above, (6) correct placement of unit in iterative measurement, (7) keep track of number of moves in number six above, (8) align correct end of ruler with object, and (9) report correct length in cm.

Because of the small number of test items (nine), the reliability coefficients (KR-20) of the posttests were rather low. Therefore, the Spearman-Brown formula was used to project the reliability of the tests based on eighteen and twenty-seven items. The data are shown in Table 1.

In order to examine another interesting concept relating to the underlying theories, general mental ability (GMA) data were secured from student files in the form of Metropolitan Readiness Test scores which were administered to the children at the end of their kindergarten year as part of routine procedures.

The criterion for judging that the Metropolitan Readiness Test was an acceptable measure of general mental ability was the moderate correlation

(.76) given in the test manual (Hildreth, Griffiths, and McGauvran, 1965, p. 12) between the MRT and the Pintner-Cunningham IQ Test. Another study by Wallbrown, Wallbrown, and Engin (1974, p. 139) found the correlation between the MRT and the Slosson Mental Ability Test to be .75. These correlations seemed high enough to warrant using the MRT as a measure of general mental ability.

Findings

In order to test the first hypothesis, an analysis of variance was run on each group's first posttest scores crossed with the T1/T2/T3 factor. The table of results is shown in Table 2. It can be seen that the obtained F on Source B was significant. In order to delve further into this difference, t tests were run to examine whether the group taught under the manipulative mode (EE-T3) did better than the groups taught under the graphic mode (IE-T2) and the abstract mode (SE-T1).

The t obtained when comparing T3 and T2 was significant at the .05 level ($t=3.74$, $df=26$). The t obtained when comparing T3 and T1 was not significant at the .05 level ($t=2.41$, $df=37$, $.05 < p < .10$).

The data support Hypothesis 1, in part. That is, students scored significantly higher under the EE mode than under the IE mode. But they did not score significantly higher under EE than under SE.

When Source A (C/NC) in the same table is examined, it can be seen that the F was not significant. Therefore, Hypothesis 2 (C would score higher overall than NC) was not supported.

In order to test the third hypothesis, an analysis of variance was run on each group's iteration subtest scores crossed with the C/NC factor. The results are presented in Table 3. It can be seen that the obtained F on Source B

(C/NC) was significant. Therefore, Hypothesis 3 was supported. This means that C did better on iteration items than NC.

Post hoc correlational analysis suggested that general mental ability and the conservation measures were moderately, but significantly correlated ($r=.292$, $n=49$). Therefore, an analysis of covariance was run on the iteration data with GMA as the covariate. The covariance summary table is presented in Table 4.

It can be seen that when GMA was accounted for by the covariance analysis, the C/NC factor (Source A) was no longer significant. Therefore, Hypothesis 3 is not supported when statistical control for general mental ability is applied.

This means there were no significant differences between C and NC even on iterative measurement items. This is interesting because Piaget's theory would predict that the presence or absence of length conservation would be most noticeable on iteration items. It appears that initially observed differences may have been accounted for by a combination of the students' GMA and C/NC status.

Conclusions and Discussion

To return to the theories with which we began the study, we ask: What do the data support in a real classroom situation?

Piaget's (Piaget, Inhelder, & Szeminska, 1960) theory implies that only conservers of length should be able to understand the concepts underlying linear measurement, particularly iterative measurement. For this reason it was hypothesized that length conservers would perform better on linear and iterative measuring tasks than nonconservers.

The results of the study do not support these predictions. Scores of C and NC on the posttests were not significantly different. A point

however, is that the results were consistently in favor of the C. That is, conservers' mean scores were consistently higher than those of nonconservers. In fact, the analysis of variance performed on the iteration scores yielded a significant F ratio. However, when general mental ability was accounted for by analysis of covariance, the F was no longer significant. This suggests a difference, but one that is not clear-cut.

Bruner's (1966) theory of instruction suggests that instruction is most effective when new concepts are presented first in the enactive, then the iconic, and lastly the symbolic mode.

The results of the study tend to support this. Posttest scores from the enactive mode were significantly higher than scores from the iconic mode and higher, but not significantly so ($.05 < p < .10$), than those from the symbolic mode.

A number of implications for classroom instruction seem warranted:

1. Manipulative experiences should precede graphic and abstract ones when introducing new topics.
2. Conservers and nonconservers of length may be taught relational terms and the use of a ruler to measure objects shorter than the ruler.
3. Instruction on iterative measurement should be in the manipulative mode until children conserve length. But instruction should not be postponed entirely, because there were many nonconservers who did indeed learn to measure iteratively.

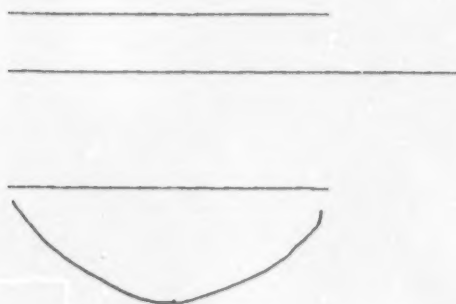
In summary, this study attempted to pull together two theories and to relate them to an actual classroom situation. The only instructional modes used were the ones in the first column of the matrix (Figure 1). Since the goal of education is to help children progress to more abstract modes of thinking, the remaining untested instructional modes should also be of interest to educational researchers. Furthermore, the only aspect of Piaget's theory

addressed in the study was that of length conservation. Clearly there are vast areas in his theory of cognitive development that need to be tested as to their implications for classroom instruction.

The job is far from complete.

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SAMPLE LENGTH CONSERVATION ITEMS



MATRIX OF INSTRUCTIONAL MODES

TEACHER INPUT	STUDENT OUTPUT		
	E	I	S
E	EE	EI	ES
I	IE	II	IS
S	SE	SI	SS

FIGURE 1. CELLS OF INPUT OUTPUT MODES OF INSTRUCTIONAL OPTIONS

		STUDENT OUTPUT		
		E	I	S
TEACHER INPUT	E	I	I OR II	II OR III
	I	I OR II	II	II OR III
	S	II OR III	II OR III	III

I = PRECONSERVATION

II = CONSERVATION

III = POSTCONSERVATION

FIGURE 2. A MATRIX COMBINING BRUNER'S MODES OF INSTRUCTION
AND PIAGET'S COGNITIVE LEVELS

T GROUPS		WEEK 1 (ABSTRACT)	WEEK 2 (GRAPHIC)	WEEK 3 (MANIPULATIVE)
1	R	C	C	C
	R	NC	NC	NC
2	R		C	C
	R		NC	NC
3	R			
	R			NC

FIGURE 3. A GRAPHIC REPRESENTATION OF THE DESIGN

(N = 22/CELL; 11 C AND 11 NC)

TABLE 1

RELIABILITY COEFFICIENTS (KR-20) OF THE
9-ITEM POSTTESTS AND PROJECTED RELIABILITY
COEFFICIENTS OF 18- AND 27-ITEM POSTTESTS

TEST	9-ITEM	18-ITEM	27-ITEM
SE	0.58	0.74	0.81
IE	0.78	0.87	0.91
EE	0.45	0.62	0.71

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE
FOR EACH TREATMENT GROUP ON THEIR FIRST POSTTEST
CROSSED WITH CONSERVERS/NONCONSERVERS

SOURCE	df	MS	F
A (C/NC)	1	1.52	0.67
B (T1/T2/T3)	2	19.41	8.52*
AB	2	0.11	0.05
ERROR	60	2.28	

* $p < .001$

TABLE 3

SUMMARY OF ANALYSIS OF VARIANCE
FOR ITERATION SUBSCORES

SOURCE	df	MS	F
A (T1/T2/T3)	2	0.41	1.78
B (C/NC)	1	1.23	5.33*
AB	2	0.05	0.20
ERROR	60	0.23	

* $p < .05$

TABLE 4

ANALYSIS OF COVARIANCE SUMMARY TABLE FOR TWO
LEVELS OF CONSERVERS AND THREE LEVELS
OF TREATMENT ON THE CRITERIA OF
ITERATIVE SCORES. COVARIATE IS METROPOLITAN
READINESS TEST SCORES

SOURCE	df	MS	F
A (C/NC)	1	0.61	3.18
B (T1/T2/T3)	2	0.17	0.89
ERROR	41	0.11	